



FINAL REPORT

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USE OF MAPS, GTE AND UARS – MLS DATA IN UNDERSTANDING TROPOSPHERIC PROCESSES CRITICAL TO MODEL DEVELOPMENT

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Two of the major problems in using meteorological models to explain observed tropospheric trace constituent distributions and thereby to understand the global budgets of the tracers are to properly define the vertical layered structure in the free atmosphere, and to understand the contribution of advection processes in generating horizontal inhomogeneities at all scales. We proposed to tackle these problems through the examination of an extensive collection of trace constituent data from research and commercial aircraft in conjunction with meteorological data from the European Center for Medium-Range Weather Forecasts. The physical mechanisms responsible for these advection and layering processes were explored and their implications for theories and models assessed. In addition, we calculated examples of how thin layers (not currently resolved by models) affect the radiative heating/cooling rates.

We developed an improved algorithm for trace constituent layer detection [Stoller et al., 1999], and used it to analyze over 100,000 km of ozone and humidity vertical profiles collected by instruments piggybacked on commercial aircraft. The same method was also used to examine ozone, humidity, carbon monoxide, and methane data from the NASA Pacific Exploratory Missions [Stoller et al., 1999]. The major conclusions from these studies were that tropospheric trace constituent layers are ubiquitous, and that their characteristics are remarkably universal [Newell et al., 1999]. For example, approximately half of the layers were of the high-ozone/low-humidity type, regardless of season or geographical region.

Analysis of seasonal variations and dependence on local stability of layers showed that, for mid to high latitudes, there was a summer peak in the number of layers per kilometer profiled. For tropical Asia the peak occurs earlier in the spring. The stability analysis revealed that the majority of the high ozone/low water vapor layers have higher stability than the surrounding environment. Together, these results support the notion that ozone layers coming in from the stratosphere play a large role in creating tropospheric layers, whether by themselves or by capping buoyant pollution plumes. This, in turn, has important implications for the transport (especially in the vertical) of trace gases and how it is represented in models [Thouret et al., 1999].

We have also performed radiative heating/cooling calculations on some observed layer structures, and have demonstrated that the sharp edges on humidity layers can have strong local effects of self-stabilization (dry layers) or destabilization (wet layers), and have suggested that clear-air turbulence might result from the latter case through convective instability [Stoller et al., 1999; Newell et al., 1999].

We put a "microscope" on one particular kind of layer (tropopause fold) and used fine-scale in-situ measurements plus data from an ozone lidar and microwave temperature profiler to study the instabilities that led to stratosphere-troposphere ozone transfer [Cho et al., 1999d]. We observed both convective instability from breaking gravity waves and Kelvin-Helmholtz instability from wind shear. The former type appears to be an important source of 3D turbulence that had previously not been considered for tropopause folds.

We also systematically analyzed the mesoscale variabilities, not only of the trace constituents, but also of the aircraft-measured dynamical variables [Cho et al., 1999b]. We learned that, in the free troposphere over the ocean, vortical modes and/or quasi-2D turbulence dominated in nonequatorial latitudes, while gravity waves were more prevalent in the equatorial region [Cho et al., 1999c]. One of the implications of this result is that the characteristics of horizontal tracer advection should be different for the two latitudinal regions, and that the possibility of inverse energy cascade in the extratropics makes subgrid parameterization of models more difficult.

Structure function and multifractal scaling analyses were used to examine water vapor measurements obtained with a NASA/Langley laser hygrometer that provided a superior 10-m resolution. With this technique we were able to quantify the intermittency and roughness of the water vapor field, and was able to show distinct differences between the boundary layer, free troposphere tropics, and free troposphere extratropics [Cho et al., 2000].

Finally, in order to help publicize the accomplishments of the MOZAIC program (an European venture) in the U.S. and try to stimulate interest in a similar program for American airlines, we wrote an article for AGU's newspaper, Eos [Cho et al., 1999a].

Publications

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